TECHNICAL ADVISORY GROUP ISSUE SUMMARY
CONTROL TECHNOLOGY AND OPTIONS

Issue Background

The attached tables identify and list the mercury control technologies appropriate for utilities in Wisconsin. These tables also include additional information concerning those technologies including mercury reduction levels, plant impacts, fly-ash impacts, installation concerns, installation schedules and technology availability. The control technologies have been sorted into three groups that relate to their expected availability.

Commercially Available - A mature technology currently available and in common use that does achieve mercury emission reductions. However, these technologies were not specifically developed for mercury removal and their performance could be enhanced through adaptation and evaluation.

This group would also include technologies that were specifically designed for mercury control and were successful in full scale testing.

Commercially Emerging - A technology that is currently undergoing full scale testing indicating no major barriers to moving to the next phase, commercial availability. This could be a minimum of 2 to 3 years or greater than five years. This does not mean the technology could not be installed at this time, however full scale testing would have to be performed on each unit. This phase usually includes testing on a limited number of installations to gain sufficient knowledge for widespread application of the technology.

Developing - A technology that is in the initial phases of research or pilot scale testing. This would typically indicate that the technology is 5 years to 10 or more years away from being commercially available. A technology that is an adaptation of an existing or commercially emerging application may be commercially available sooner. Technologies that advance to pilot testing have a greater certainty of becoming commercially emerging and proceeding to full scale testing.

Key Points

Commercially Available Technologies (Table I.) There are several options available to pursue low level reductions based on fuel switching (subject to fuel availability) and improving the current mercury-particulate contact. Relatively high reductions could potentially be achieved through the installation of fabric filter systems (no injection) with average reductions of 73% for subbituminous and 89% for bituminous fuels (based on limited testing). For all of these approaches the actual reduction on an individual unit may vary significantly.

- The fuel switching options are generally limited to replacing 10 – 20% of the current fuel before firing limitations occur. Also, significant consideration must be given to their availability, supply, and cost. Reductions are based on the incremental difference in fuel content.
- Plant modifications to increase contact time and particulate removal efficiency are limited by the Hg^{++} speciation and therefore can vary significantly for each unit. Low to moderate additional reductions occur only if the unit has insufficient particulate / Hg^{++} contact time.

- Major modifications or add-ons can yield moderate to high reductions. However, most of these options can see significant variation in the mercury reductions between units. The best performing and consistent would be the fabric filter based technologies and even they showed considerable variation. The ICR data showed reduction for subbituminous coal ranged from 48 to 86% with a 73% avaerage reduction and for bituminous ranged from 35 to 99% with an 89% average reduction. Some units in the U.S.currently inject lime for SO2 scrubbing which on average resulted in high Hg reductions, but in some cases this seemed to decrease reductions.
- High level reductions (90 – 100%) can be garnered through the installation of new gas fired units, but this is limited to areas with gas availability and may be more subject to cost considerations integrated gasification combined cycle units (solid fuel gasifiers - IGCC) which have a much smaller flue gas volume that can be economically controlled with an activated carbon bed. Several IGCC units have been permitted and in operation for a number of years but is still a maturing technology.

Commercially Emerging Technologies (Table II.) In addition to those commercially available, technologies that are targeted for availability in the next five years for reductions in the 90% range seem to focus on fabric filter technologies with AC injection and oxidizing catalysts (typically with a wet scrubber). Although, techniques may be developed to achieve higher reductions without a fabric filter system using AC injection this will still result in major fly-ash impacts. Additional options are expected to become available to achieve low to mid level reductions that will allow the use of multiple technologies to reach high level reductions. For example, enhanced coal washing with predicted reductions of 55 to 68%. But these techniques may not be widely available and applicable to all units. In general these technologies have limited experience relative to potential long-term impacts and therefore carry various levels of added risk until further testing is conducted.

- Several options were identified that do not require significant plant retrofit modifications and which are expected to provide moderate levels of addition mercury reduction. Enhanced fuel washing may potentially remove up to 55 to 68% of the mercury prior to entering a boiler. Flue gas cooling technologies generally aid in condensing mercury vapor to particulate surfaces with research indicating that it may not be applicable to sub-bituminous fired units. Both options would most likely be utilized in conjunction with other control approaches to achieve high reduction levels.
- The options that obtain high mercury reduction levels are mainly obtained through the injection technologies or flue gas oxidation methods.
- The injection technologies can be utilized either before existing particulate control devices (ESP or FF) or prior to a newly installed collection device (most commonly considered is the compact fabric filter).
- The most prevalent sorbant being tested is activated carbon with 80% and upwards expected removal efficiencies when injected prior to either an existing or new fabric filter. For existing ESP applications (approximately 80% of Wisconsin units) this removal is expected to be a maximum 60 – 70% (based on 1 full-scale test) and would be more variable by unit than the fabric filter approach. AC injected prior to existing equipment results in a flyash-AC mixture that is unusable for cement manufacturing. Without this reuse the flyash would most likely be landfilled thus losing a revenue and incurring additional costs and environmental impacts.
- EPA anticipates that circulating fluidized contacting beds, similar to lime injection absorbers for acid gases, can be used to maximize contact of sorbents and mercury to reduce sorbent

use and increase removal efficiency.   This technique can be used either before an existing ESPs or fabric filters but this may be limited on some plants by physical space constraints. This application is not as far along to be called commercially emerging, but it is likely to be adapted on a similar timeframe or shortly thereafter.

- Another option is injecting liquid Sodium Tetra-sulfide to create a mercuric sulfide salt which is readily removed by the existing particulate control devices and is very stable thus avoiding any potential release issue. Although, this process shows much promise it has primarily been tested on a municipal waste incinerator with a 86 to 93% reduction.
- The oxidizer technologies convert Hg^o to Hg++ so it is more readily attached to particulate or soluable in a wet scrubber solution. Test on catalyst beds specific for converting NOx to N2 (SCR) have indicated significant oxidation rates may be possible. In fact several papers have indicated oxidation by SCR seen at levels greater than 90% in some cases. Building on this information, efforts are centered on development of a HG specific oxidizing catalyst to target 80 – 90% or greater reduction for all fuel types. Chemical oxidants injected into the flue gas or used in a solution are being developed but the expected reductions are not as high at this time. The oxidizing technologies can be used prior to ESPs, FF, and wet scrubbers and constitutes a major installation. The Power Span technology is an integrated system that electronically oxidizes NOx, SOx, and Hg for removal in a wet system.

Developing Technologies (Table III.)   The 5 year and beyond timeframe brings the significantly increased potential for additional high level reduction options including: processing of the fuel to remove mercury, alternative sorbents to activated carbon, additional mercury oxidizing methods, and mercury filter beds. All of these alternatives focus on eliminating the potential impacts and lowering costs versus the currently available or emerging techniques. Of particular interest is the alternative sorbents as they would build on or replace the activated carbon using the same equipment. Sorbents are being researched that potentially to not have fly-ash impacts and/or that will function as a multi-pollutant absorbent.

- The longer term development efforts are focusing on technologies to directly remove the mercury, eliminate the associated control impacts, create more viable multi-pollutant options and reduce costs. Reductions are based on initial research results.
- All of these processes are targeting near 90% or greater mercury reductions. Although there may have been some initial testing under flue gas conditions, these technologies have not preceded to the point of structured pilot testing program to determine feasibility and effectiveness potential.
- One option for the fabric filter is using material that either directly absorbs the Hg or converts it to Hg++ so it can attach to the captured particulate.
- The alternative sorbents are focusing on several issues: 1) Eliminating any re-use impact associated with activated carbon and also the potential release of mercury. 2) Improve the removal efficiency so they can be used to gain high reductions in existing systems (ESPs). 3) Develop materials that will absorb SOx, NOx, and potentially other pollutants. 4) Reduce the sorbent material and processing cost. Development of alternative sorbents is a focus to replace activated carbon. Therefore, it is expected that some of these sorbents will occur sooner than the 5 to 10 year window and follow closely behind the AC technology.
- The fixed filter and plate technologies are promising technologies that are of high priority. Some of these technologies are approaching the pilot-testing phase to determine actual viability in flue gas conditions (e.g. gold plate).

Ultimate Fate of Mercury

A question raised by the TAG and other national groups involved in evaluating mercury control is asking what happens to the mercury once it is captured? Is there a potential for the mercury to volatilize or leach into the environment once it is captured? There is no clear answer at this time, but further research has been initiated to make this determination by EPA, DOE, and in partnership with other organizations. Other important points include:

- The flyash that is currently collected to some degree already contains mercury so this may not be a new issue. Therefore additional mercury control may add to this potential problem or may bring about methods that work to minimize the potential re-release of mercury.
- Currently the majority of flyash is used in cement manufacturing followed by road fill and de-icer use, with the remainder landfilled in utility landfills.
- EPA identified potential release issues from mercury containing fly-ash in landfilling, structural fill, cement manufacturing, wallboard manufacturing (Wet Scrubber sludge), and asphalt manufacturing.
- The ultimate fate of mercury captured by carbon is undetermined at this time. USEPA has indicated that the potential release from landfilling or reuse in applications such as gypsum board manufacturing is expected to be minimal, but further research has been initiated to make this determination.
- The addition of activated carbon may aid in locking up the mercury and preventing release in the re-use applications. Using injection prior to a fabric filter minimizes the amount of flyash with additional captured mercury. This may then be handled separately, but would represent an additional annual cost.
- There are potentially emerging technologies that may eliminate or minimize this concern. For commercially available these include fuel switching or the activated carbon bed. For commercially emerging these may include the activated carbon technologies, the enhanced coal washing, and the sodium tetra-sulfide injection.

Balance of Plant Impacts

For existing sources, an important consideration when retrofitting control equipment at a plant is the impact of the controls on the balance of plant operations. This may include impacts such as fans, fan power, control upgrades, foundations, structural stability, and physical space constraints allowing room to install new equipment (e.g., baghouses) or storage silos (e.g., AC storage). The results of these impacts may include both long-term losses in efficiency and also increased on-site plant energy consumption to run equipment, thereby decreasing overall generation capacity and increasing costs. Additional reviews by the TAG would be necessary to determine the potential magnitude of the balance of plant impacts for those technologies listed in the summary table below, and in some cases, may not be quantifiable for emerging technologies which have not been implemented full-scale.

Multi-pollutant Approaches

The multi-pollutant approaches focus on NOx, SOx, Fine Particulates (PM2.5), CO2, and other toxic metals or gases, but may include others. These pollutants are anticipated to be the subject of future regulations in Wisconsin with the possible exception of CO2. A reduction registry is being developed to address early reductions of any pollutant.

- The NOx SCR technology may improve oxidation of mercury to Hg++ for increased removal in front of a particulate control device or wet scrubber.
- Wet Scrubbers and dry lime injection followed by a fabric filter are the primary available means to controlling SOx emissions and fine particulate. High mercury removal in the wet scrubber requires development of the oxidizing catalyst. Dry scrubbing with fabric filters has resulted in variable mercury removal therefore further research is needed to consistently address both SOx and mercury at one time. The product of each approach is still subject to the ultimate fate of mercury question.

Cost Considerations

- The cost originally projected by DNR to meet a 90% reduction ranged from 0.0008 to 0.0051 $/kWh based on activated carbon injection prior to existing control equipment or an installed fabric filter. The cost and control level potential is undergoing revision to address fly-ash disposal costs, plant impacts, current sorbent costs, and compliance and growth issues.

- USEPA has indicated the expectation that mercury control costs in comparison will lie mostly between the costs for low-NOx burners and SCR for NOx controls. However, this estimate does not account for the high amount of sub-bituminous coal used by Wisconsin units.

- A multi-pollutant approach has the potential to significantly reduce the cost attributed to mercury control. USEPA indicates this corresponds with the development of multi-pollutant sorbents, oxidizing catalysts and agents, and the use of fluidized contacting beds.

I. Commercially Available Technologies and Options

Technology	Avg. % Hg Red.	Install Years	Short Term Plant Impacts	Long Term Plant Impacts	Fly-ash	Multi-pollutant	Comment
Natural Gas Sub	10 – 15%		Efficiency loss			NOx, SOx, PM, CO_2	Limited Co-fire, Limited Availability
Coke Substitution	< 10 – 20% Incremental	< 1	Increased metal HAPs Emissions				Limited Co-fire
Low Hg Coal	Low – Incremental	< 1	Efficiency loss?				Compatibilty with units is uncertain
Biomass Substitution	10 – 15%	< 1					Limited Supply / Limited Co-fire
Duct Modifications / Contacting Bed	Incr. contact time Low – Hg^{++}	2					Subject to space limits
ESP hotside converted to coldside	Sub............3% Bit........... 35%	2					Subject to space limits
Convert 1 ESP field to wet	Low – Hg^{++}	2	Sludge handling			PM	May be higher for units / existing short residence times
Convert 1 ESP field to pulse-jet	Sub...........< 73% Bit............< 89%	2				PM	Red. % based on full size fabric filters
Spray Dry Lime Injection	ESPc........0 – 50% FF.........23 – 98%	2	Incr. Energy			SOx, PM	
Wet Scrubber	Low – Hg^{++}					SOx, PM	May be higher for units / existing short residence times
Add-on Fabric Filter	Sub...........73% avg Bit............89% avg	3	Incr. Energy			PM	May replace ESP for space
Fixed Activated Carbon Bed	90 – 95%		Incr. Energy				High reductions require large bed
New Gas Plant	100%	3				NOx, SOx, PM, CO_2	Plants can only be built where gas supply is available
New Coal Plant (IGCC)	90 – 95%	5 +				NOx, SOx, PM, CO_2	Control w/ AC bed

II. Commercially Emerging Technologies and Options (2 - 5+ to Commercially Available)

Technology	Avg. % Hg Red.	Install Years	Short Term Plant Impacts	Long Term Plant Impacts	Fly-ash	Multi-pollutant	Comment
Enhanced Coal Washing	55 – 68%	< 1					Product from washing?
Spray Cooling	Bit – Low	< 1					No benefit shown for Sub
AC Inj. Prior to Existing ESP or FF	ESP: 60% - variable FF: 80% +	2	Incr. Energy	Potential Shortening of Equip Life	Renders it unusable for cement		
Add on compact Fabric Filter + AC Inj.	90% +	3	Incr. Energy		Minimal		
Power Span	80 +	< 1	Incr. Energy	Liquids disposal issue		NOx, SOx, PM	
Sodium Tetrasulfide Injection	82 to 93% on Incinerator Test	< 1					
Catalyst Bed Oxidizer + Wet Scrubber	70 – 90%	3				SOx, PM, CO2	
Chemical Oxidant + Wet Scrubber	Incr. 5 – 10%	3				SOx, PM, CO2	
SCR catalyst	Variable – current research initiative	3				NOx	

III. Developing Technologies and Options (> 5 Year to Commercial Available)

Technology	Avg. % Hg Red.	Install Years	Short Term Plant Impacts	Long Term Plant Impacts	Fly-ash	Multi-pollutant	Comment
Hydro Thermal Fuel Cleaning	85 – 99%	< 1					
Carbon Bags for FF	70 - 90%	< 1					
Catalytic Bags for FF	90%	< 1					
Alternative Sorbents for Injection	High	< 1					
Solid selenium filter	High	2					
Gold honeycomb	High	2					
MerCap - Gold Plate + Heat Exchanger	High	2					